

Note: Researchers at Carnegie Mellon University (CMU) and Worcester Polytechnic Institute (WPI) conducted the following research collaboratively. This document is the CMU version. Neil Heffernan at WPI is submitting the same final report for the WPI version.

### **Final Report**

Grant Number : N00014-03-1-0220

Principal Investigator: Kenneth R. Koedinger

Institution: Carnegie Mellon University, Pittsburgh, PA 15213-3891

Grant Title: Affordable Cognitive Modeling Authoring Tools using HCI Methods: Carnegie Mellon University Portion

Award Period: Dec, 1<sup>st</sup>, 2002- Nov 30<sup>th</sup>, 2005

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available from a website (<http://ctat.pact.cs.cmu.edu/>). We estimate that there are currently between 100 and 200 users of CTAT.

### **Accomplishments:**

We were able to show that our tools can be used to build many different rule-based cognitive models, such as a Warrior Simulator at Fort Benning (Livak & Heffernan, 2004), a Logic Tutor for internal use at CMU, and a Genetics tutor.

In preliminary controlled experiments involving basic Cognitive Tutor development tasks, we found efficiency gains due to CTAT of 1.4 to 2 times faster (Alevan, McLaren, Sewall & Koedinger, 2006). We also demonstrated across 4 different behavioral modeling projects that our tools created example-tracing tutors that drastically reduced modeling costs (Koedinger, Alevan, Heffernan, McLaren, & Hockenberry, 2004, Heffernan, Turner, Lourenco, Macasek, Nuzzo-Jones, Koedinger, 2006). Not only did we reduce the time dramatically (averaging a reduction of over a factor 5), we also reduced the experience level modelers needed.

Finally, we pushed the state of the art in data mining and machine learning support to help rule-writers (McLaren et al 2005; Harrer et al, 2005; McLaren et al, 2004b; McLaren et al, 2004a; Jarvis, Nuzzo-Jones, & Heffernan, 2004; Matsuda, Cohen, and Koedinger, 2005a; 2005b; 2005c).

### **Conclusions**

We have made excellent progress toward creating and demonstrating affordable behavior modeling through development and evaluation research on the Cognitive Tutor Authoring Tools. The central approach has been to use human-computer interaction, data mining, and machine learning techniques to create software components, smart interfaces and underlying intelligence, that speed the process of behavior modeling. Critical to our success has been creating a large user community that provides both realistic user tests and vote-with-your-feet evidence that CTAT is effectively reducing behavior-modeling costs. The 200 users of CTAT represent the largest number of users of any technology in the AHBM program. We have also provided reasonable evidence of affordability improvements.

### **Significance**

Cognitive models are used successfully throughout the Armed Forces as well as in educational and training software. However, cognitive models have traditionally been very expensive to build. This small project has produced valuable knowledge about methods that can be used to make modeling more cost effective. This project has also created a specific set of tools (CTAT) that embodies some of this knowledge, and that set of tools has led to the cost-effective creation of many new cognitive models. These models in turn lead to more knowledge as exhibited by the many peer-reviewed papers produced under this grant or related to this grant.

### **Publications**

- Alevan, V., McLaren, B. M., Sewall, J., and Koedinger, K. R. (in press). The Cognitive Tutor Authoring Tools (CTAT): Preliminary Evaluation of Efficiency Gains; Accepted for presentation at the 8th International Conference on Intelligent Tutoring Systems, Jhongli, Taiwan, June 26-30, 2006.
- Alevan, V., Sewall, J., McLaren, B. M., & Koedinger, K. R. (in press). Rapid authoring of intelligent tutors for real-world and experimental use. Accepted for presentation at the The 6th IEEE International Conference on Advanced Learning Technologies (ICALT 2006).
- Harrer, A., McLaren, B. M., Walker, E., Bollen, L., and Sewall, J. (2005) Collaboration and Cognitive Tutoring: Integration, Empirical Results, and Future Directions. In the Proceedings of the 12th

## Patents

WPI's Heffernan and CMU's Koedinger filed for a U.S. Pat. No. 60/699,624 related to the WPI version of pseudo-tutor construction.

## Awards:

This grant funding helped lead to many other successful projects that used the results of this ONR grant.

- Heffernan was awarded an NSF CAREER award half way through this grant<sup>1</sup>.
- Koedinger was awarded a \$25 million NSF Science of Learning Center grant that is now supporting the use, and further development, of the authoring tools this grant produced.
- Heffernan and Koedinger were awarded \$1.4 millions dollars to use the techniques developed during the grant to cost-effectively create a complex new cognitive model, and tutoring systems used by thousands of students inside of 2 year.<sup>2</sup>
- Heffernan and colleagues at WPI were awarded a grant to further the learning sciences<sup>3</sup>
- Heffernan and colleagues at Sonalysts were funded to demonstrate application of these techniques to help Fort Benning enable "Warrior Tutoring" inside of their simulations at Fort Benning.
- Koedinger received a 2-year grant from the Grable foundation to support the further development of the CTAT tool suite. Grant title: Authoring Cognitive Tutors, Number: 11655-1-1030164, Start: 4/12/04, End: 5/31/06

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<sup>1</sup> "Learning about Learning" NSF CARREER award to Heffernan. \$600,000.

<sup>2</sup> "Using Web-Based Cognitive Assessment Systems for Predicting Student Performance on State Exams" US Dept of Education: Institute of Education Sciences . \$1.4 million.

<sup>3</sup> Title: "Fellowships in CS to support the learning sciences and security". US Dept of Ed: Graduate Assistance in Areas of National Need (GAANN). \$804,940. PI: Ward, Heffernan, Agu and Heineman

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